Wiggling Fingers at the Force-Length Relationship

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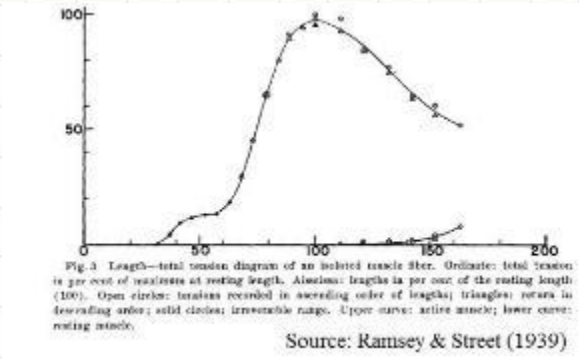
Overview

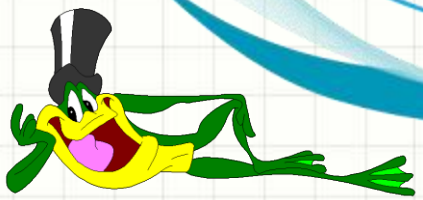
- Brief Background
- Identify the Question
- Challenges, Limitations, & Assumptions
- Methods
  - Who, What, & How
  - Analysis
- Results
- Conclusions & Question

Brief Background

- *Figure 1: Force-length curve for a single fiber.*



Source: Ramsey & Street (1939)



- Used dissected semitendinosus muscle fibers of frogs
  - *With maximum activation*

- *Figure 2: Pennation Angle Measurement*

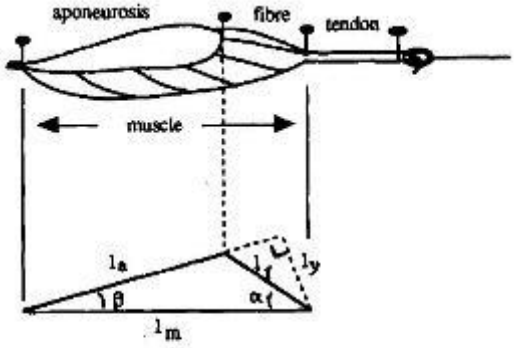


Fig. 1. Schematic representation of the GM muscle–tendon complex, markers inserted and geometrical representation of the muscle. The lengths of elements measured by cinematographic images are indicated: fibre length (l_f), aponeurosis length (l_a), muscle length (l_m), perpendicular distance between the aponeuroses (l_y), fibre angle (α) and aponeurosis angle (β).

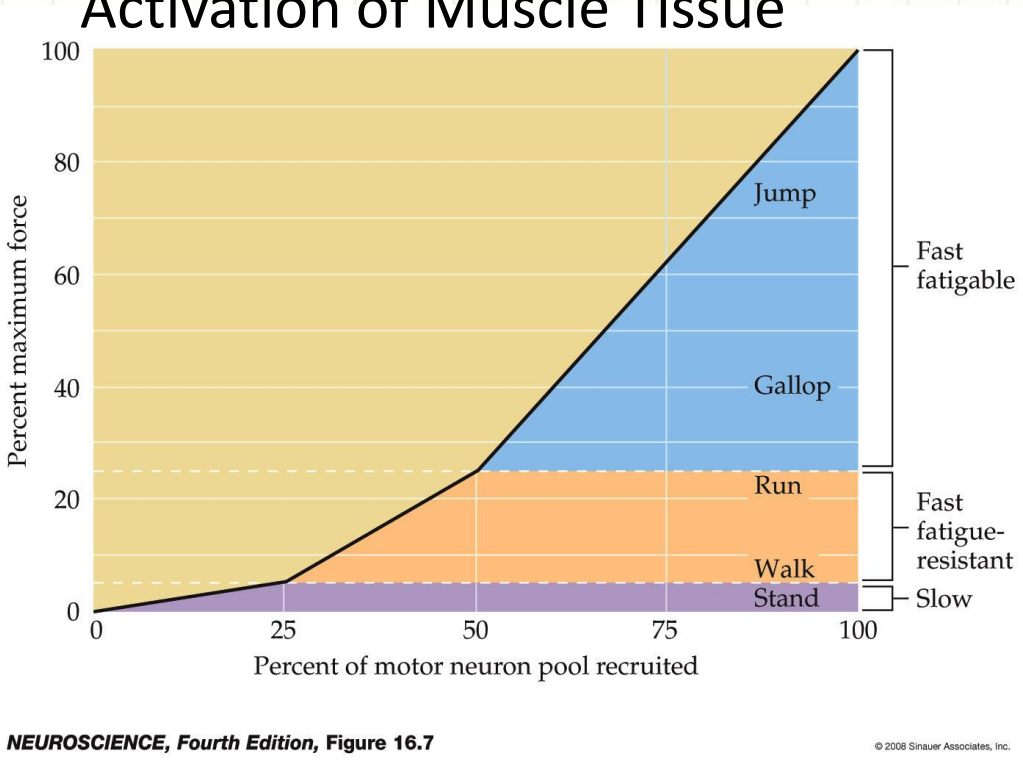
Source: Zuurbier & Huijing (1992)

- Gastrocnemius medialis muscles from rats
  - *With maximum activation*

Identify the Problem

Maximum activation will produce maximum force

Activation of Muscle Tissue



How do we define sub-maximum?

Comparison of Curves

- *Figure 3: Force length curves for separate definitions of optimum muscle length.*

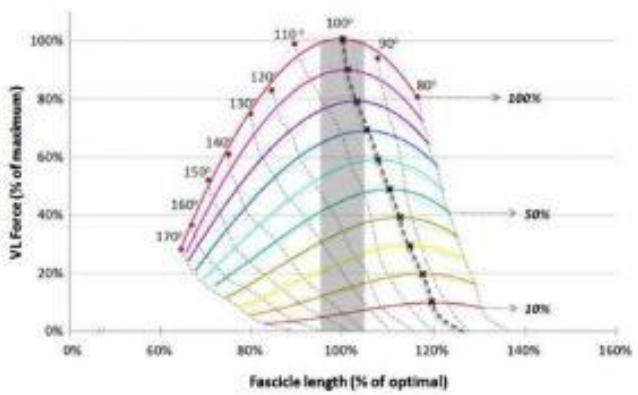


Fig. 3 Length dependence of submaximal force production based on percentages of maximal force. *Colored lines* represent the mean values for fascicle lengths at maximal and submaximal force production (0–100 %), while the *dashed lines* correspond to the different knee angles analyzed (specified in the MVC curve). Best fitting, third order polynomial approximations were made for each level of force. Note that for decreasing levels of force, by definition, peak forces occur at the same MTU length (and thus the same joint angle—i.e. 100° indicated by the *bold dashed line*) but longer fascicle lengths (indicated by the "*multiplication*" *symbols*) (color figure online)

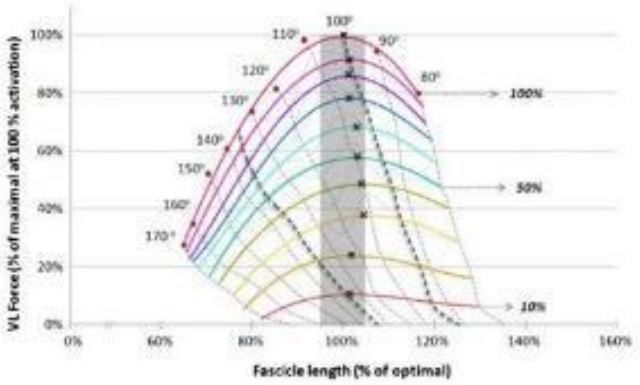


Fig. 4 Length dependence of submaximal force production based on percentages of maximal activation. *Colored lines* represent the mean values for the force generating potential per fascicle length at the different levels of activation, while the *dashed lines* are the different knee angles. Best fitting, third order polynomial approximations were made for each level of activation. Note that for decreasing levels of activation, peak forces (indicated by the *black* "*multiplication*" *symbol*) occur at similar fascicles lengths but shorter MTU lengths and thus increasing knee angles (from about 100° for the maximal contractions to about 135° for the 10 % of maximal activation—indicated by the *bold dashed lines*) (color figure online)

de Fontana and Herzog (2016)

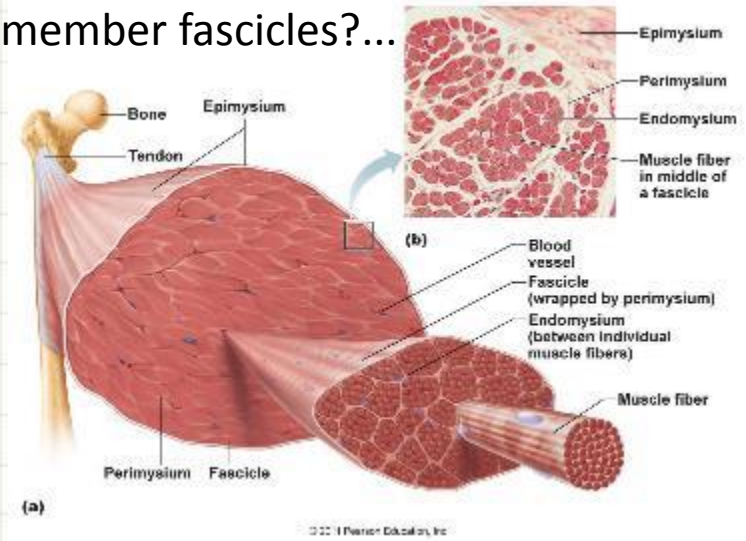
- ❑ *Sub-Maximum Force VS Sub-Maximum Activation*
  - Vastus lateralis of nine participants

Challenges, Limitations, & Assumptions

What we need to know…

I. Muscle force,
II. Muscle Activation, &
III. Fascicle length

Remember fascicles?...



I. Muscle force...

Cut out the muscle and tie it to a scale?

Or measure force at a joint…

Vastus lateralis is one of four muscles

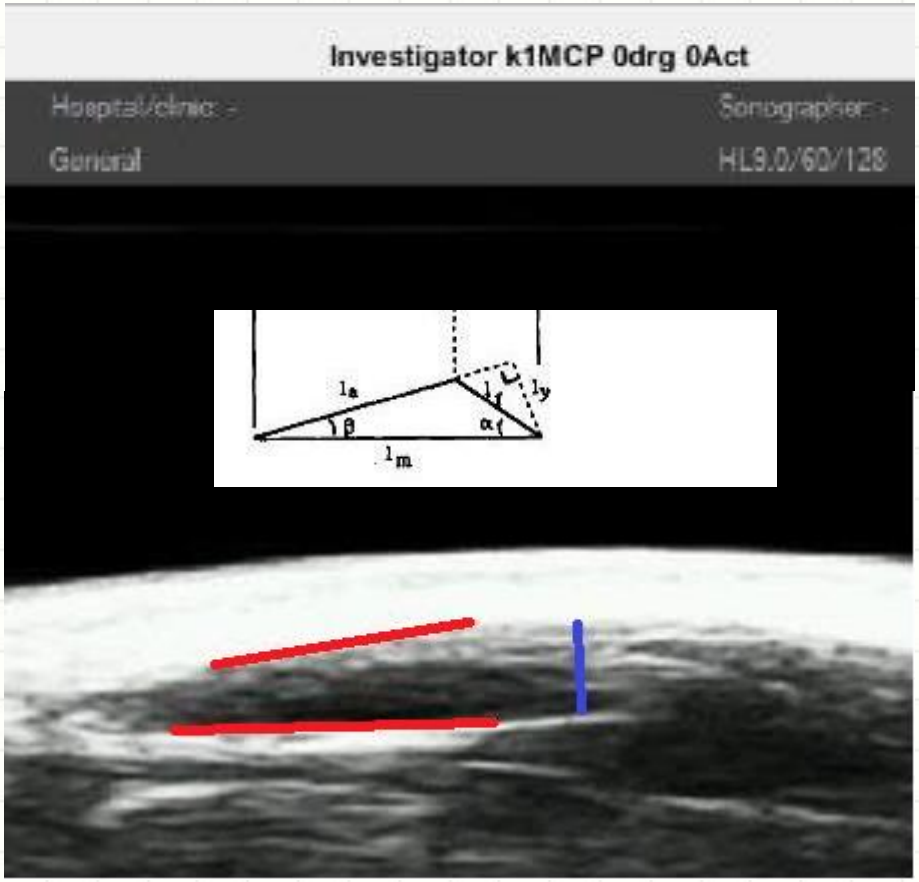
Physiological Cross Sectional Area Assumption

Or

Wiggle a finger with the First Dorsal Interosseous

II. Muscle Activation
EMG is easy for me…

III. Fascicles length



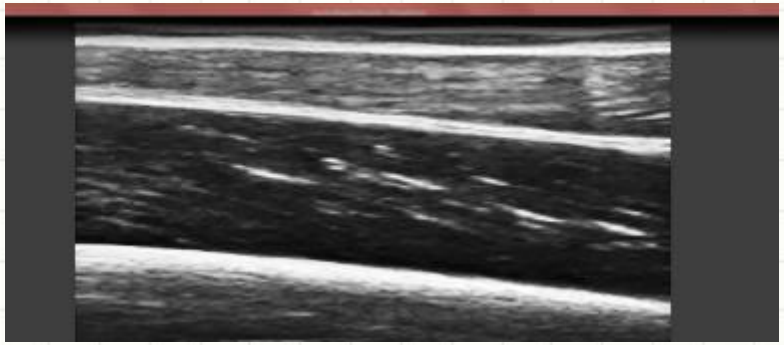
25 years later…

- we are still making the same assumptions

Today…

- live human muscle so Master Splinter lives

But take a quick look at the triceps brachii



$$\theta = \tan^{-1}(m_{red\ line} + m_{red\ line})$$

$$m_{red\ line} = \frac{|\Delta y|}{|\Delta x|} \qquad h = |\Delta y_{blue\ line}| \qquad l = h/\sin\theta$$

The Who, What, & How

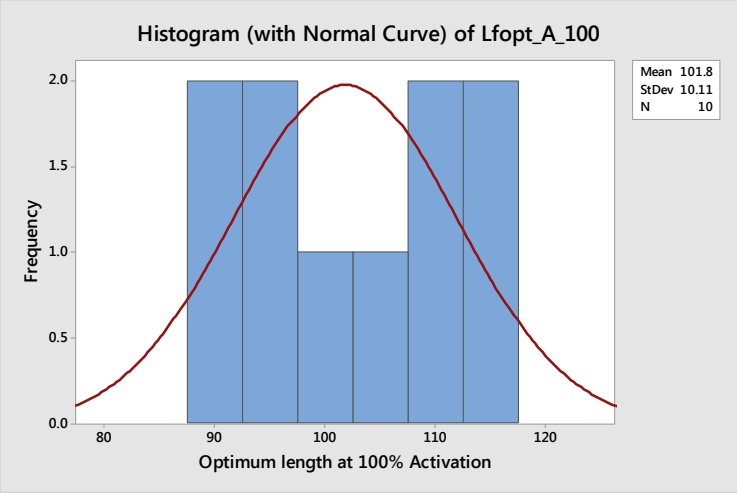
Who	• Right FDI of four live male participants & Four volunteer investigators.
What	• Force-length curves and validate the methods
How	• Collect, analyses, & re-analyses

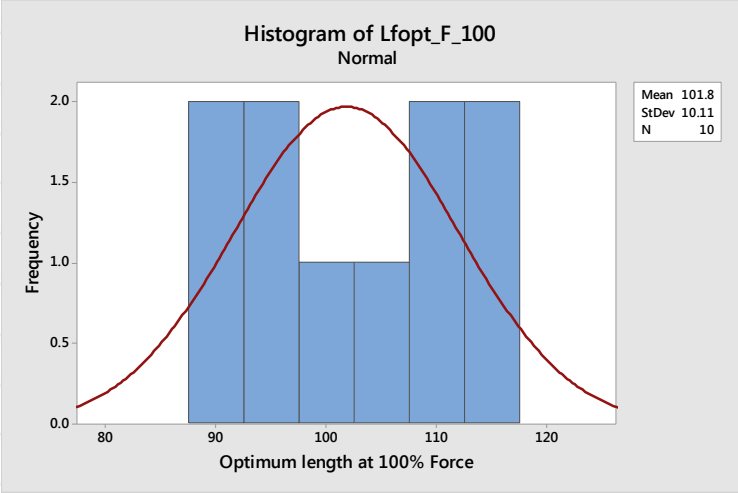
Collect

-Force, EMG, & Ultrasound

- At 0,5,10,15,&20 degrees

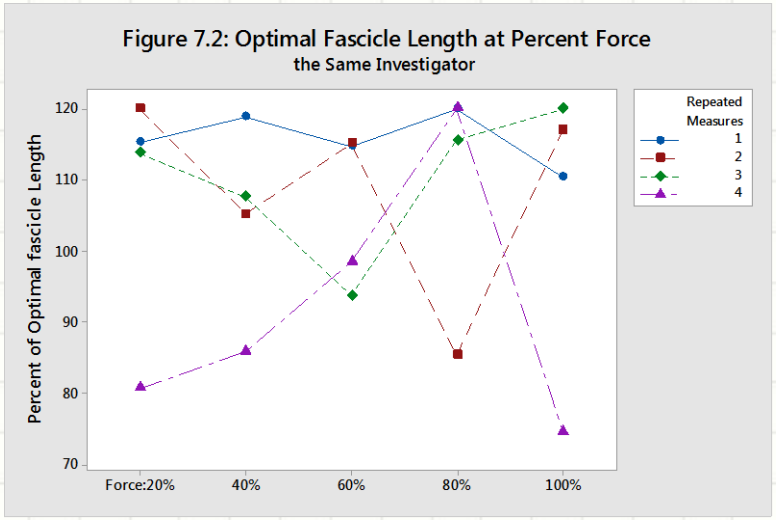
Analysis & Re-analysis

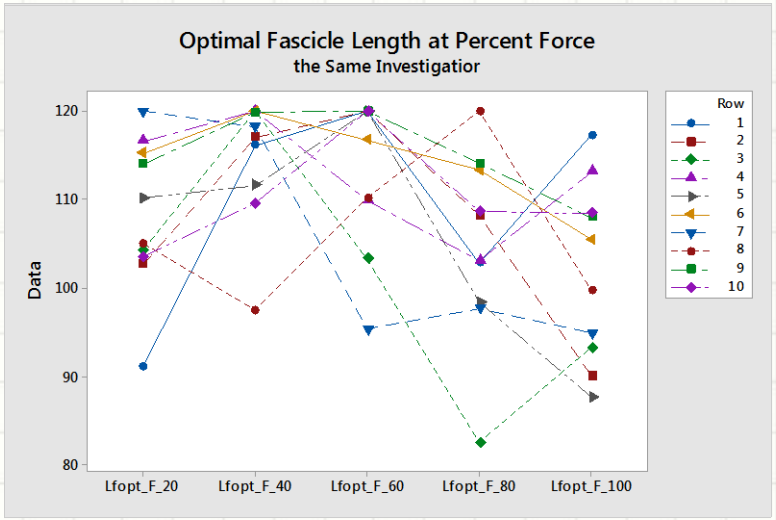




RESULTS
OF RELIABILITY TESTS

H_o: Repeated manual digitization of ultrasound images of the first dorsal interosseous is not significantly different in optimum fascicle length at 20, 40, 60, 80, and 100% percent activation or force between different investigators.

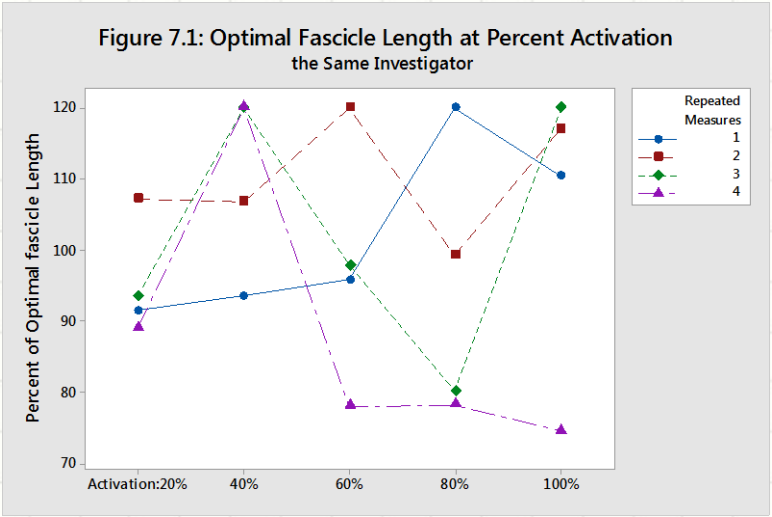


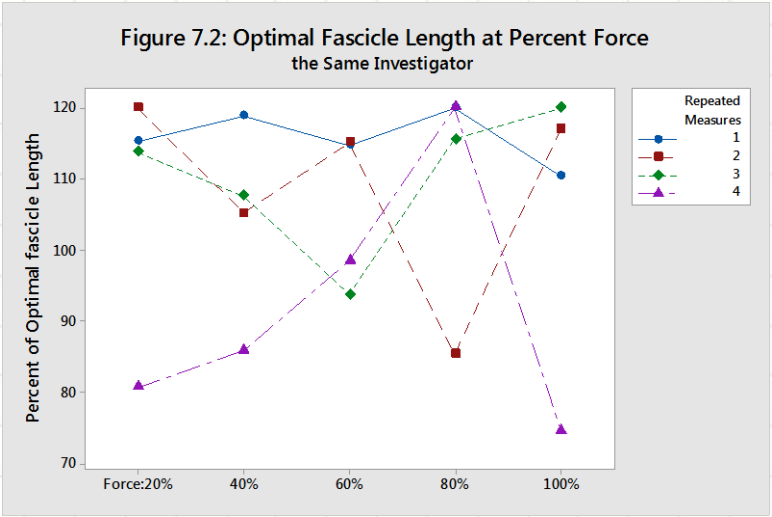


Results

of Optimum Fascicle Length Significance Test

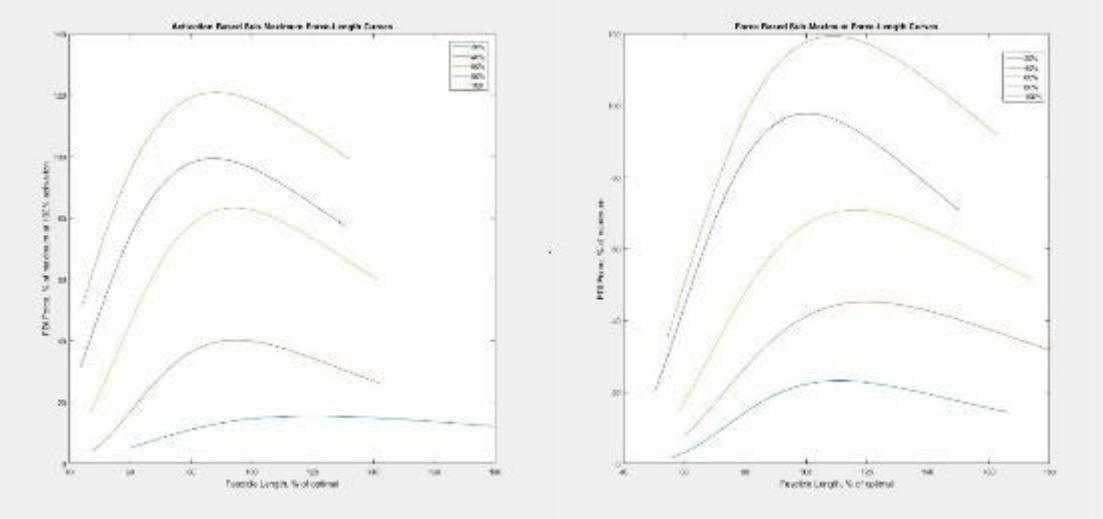
Ho: First dorsal interosseous optimum fascicle length will not occur at significantly different fascicle lengths for different sub-maximal muscle functions.



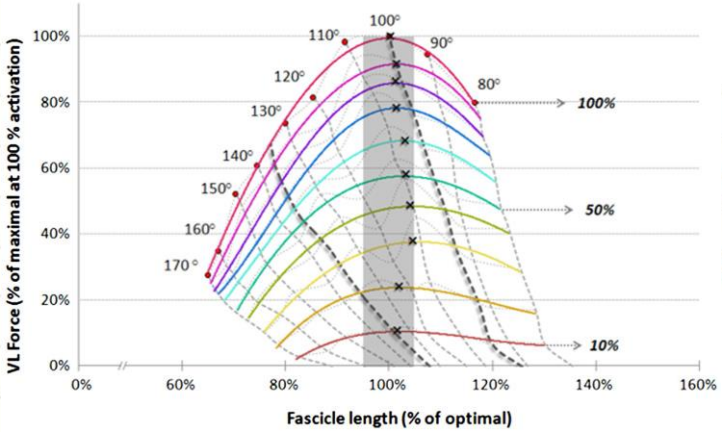


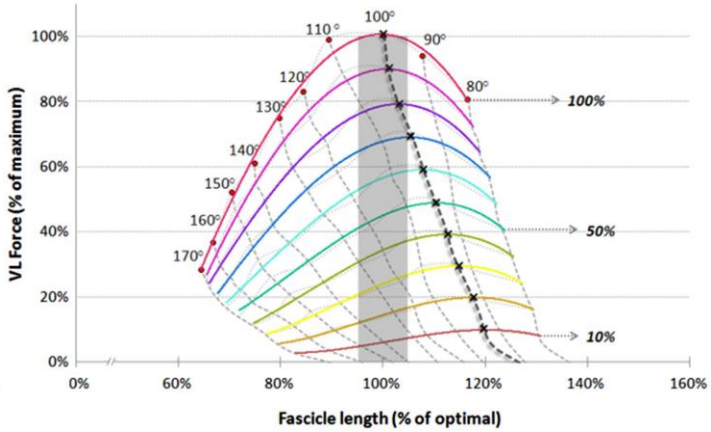
Results on a curve

Figure 6: Force-Length Curves of the First Dorsal Interosseous at Sub-Maximum and Maximum Muscle Functions



Non-significance found in the present study compared to the significance in longer fascial lengths for decreasing force-based sub-maximum muscle function by de Fontana & Herzog (2016).





Conclusions

Major challenges

- Relative size of the muscle being investigated
- Pennation angles of the FDI were not really measured, requiring a generalization.
- The FDI operates on a small portion of the ascending force-length curve, requiring force-length equation from Otten (1987)

Therefore a fundamental purpose for this thesis must exist: to test the reliability of muscle architectural measurements made by manual digitization of ultrasound images of the FDI.

Conclusions

The future

- Continue data collection while seeking more statistical power.
- Consider the triceps brachii as an alternative to the First Dorsal Interosseous.

QUESTIONS?

REFERENCES

de Brito Fontana, H. B., & Herzog, W. (2016). Vastus lateralis maximum force- generating potential occurs at optimal fascicle length regardless of activation level. *European Journal of Applied Physiology, 116*(6), 1267-1277.

Ramsey, R. W., & Street, S. F. (1940). The isometric length-tension diagram of isolated skeletal muscle fibers of the frog. *Journal of Cellular and Comparative Physiology, 15*(1), 11-34.

Zuurbier, C. J., & Huijing, P. A. (1992). Influence of muscle geometry on shortening speed of fibre aponeurosis and muscle. *Journal of Biomechanics, 25*(9), 1017-1026.